# Time Over Threshold as a measure of energy response of plastic scintillators used in the J-PET detector

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## Motivation

- J-PET detector is composed of 192 plastic scintillator axially arranged in 3-layers [1-5].
- Charge collection is replaced by **T**ime **O**ver **T**hreshold (**TOT**) measurements.
- In organic scintillation, gamma quanta interact predominantly via **Compton** scattering: only partial energy deposition.
- Relationship between energy deposition by incident photon and corresponding TOT values is non-linear [6,7].
- For the efficient identification of photons originating from different sources e.g., direct annihilation, positronium decay, pick-off reaction, a precise energetic calibration of J-PET detector is necessary.
- In framework of the J-PET detector, to study the discrete symmetries [8-11], relationship between TOT and energy loss will play the key role.

## Algorithm

**3 – Hit events were studied**

***Selection of 511 keV gamma quanta :***

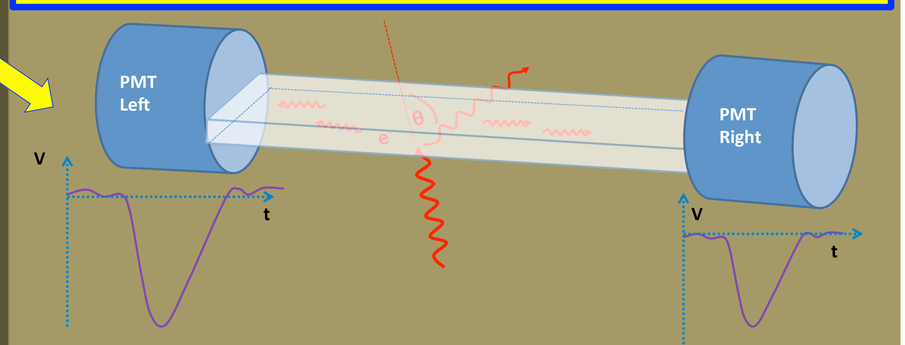
- **1st** and **2nd** hits are from **back-to-back gamma** (annihilation)
- **3rd** hit belongs to **scattered gamma,** either from 1st or 2nd.
- **Scatter test,** a measure to assign the scattered gamma to its primary interaction was implemented.

***Selection of 1274.6 keV gamma quanta :***

- **1st** hit is **prompt gamma** **(de-excitation)**
- **2nd** hit belongs to the **scattering** of prompt gamma after primary interaction.
- **3rd** hit is assumed as one of the **annihilation gamma**.

*Event selection procedure mentioned above enables us to **tag the energy of incident gamma.** The geometrical acceptance of J-PET detector allows to estimate the scattering angles of the primary Compton interactions and **hence we know the deposited energy by an incident gamma** and the **corresponding TOT values**.*

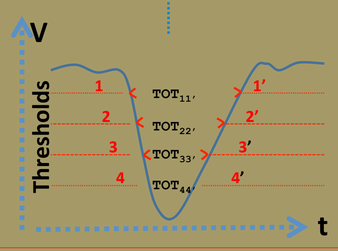
## J-PET MODULE : 500 X 19 X 7 mm$^3$




✓ **Four constant thresholds** are applied on signal

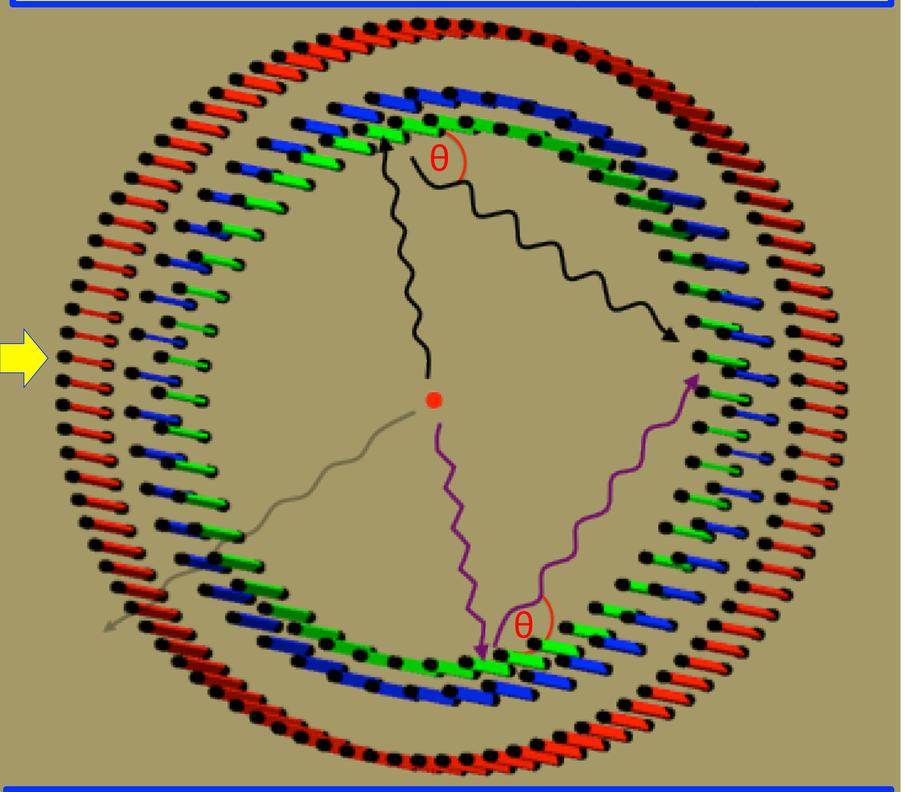
✓ **Four TOT values** , where

**TOT:** Represents the Time difference between the leading and trailing edge of the signal at a fixed threshold .

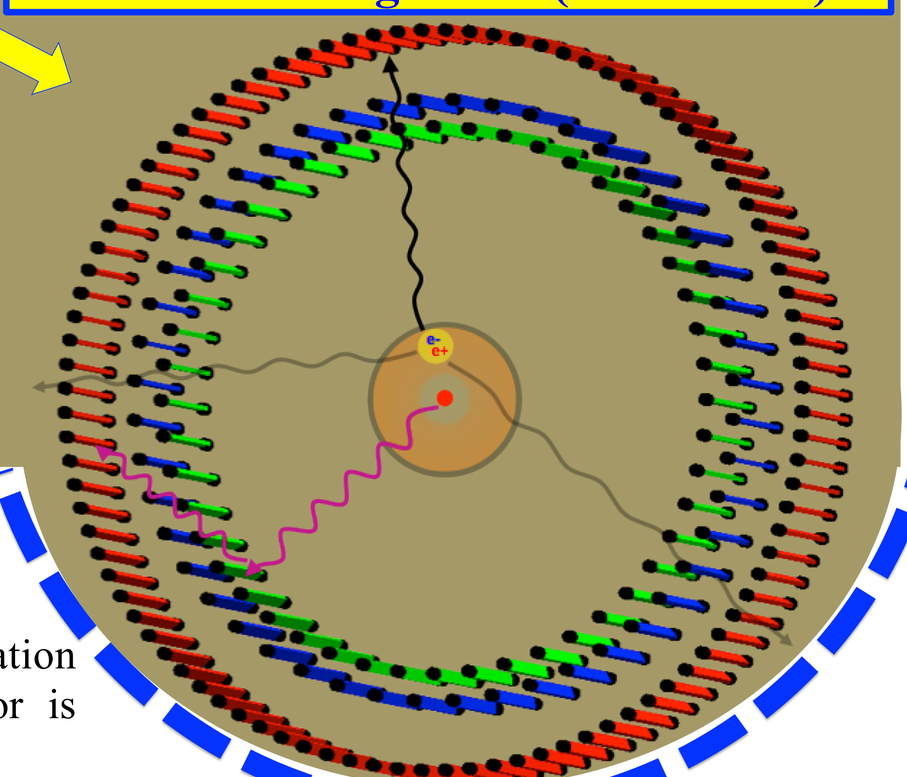



$TOT_{SUM} = \Delta t_{11'} + \Delta t_{22'} + \Delta t_{33'} + \Delta t_{44'}$

## $e^+ - e^-$ annihillation (511 keV)




## De-excitation gamma (1274.6 keV)



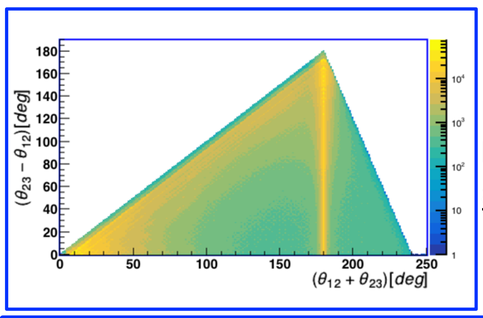

## Conclusions

☑ The state-of-art energy calibration procedure for the J-PET detector is described.

☑ Relationship between **TOT Vs Energy deposition** by incident gamma is established.

☑ Based on the developed relationship, the J-PET detector acquires the sensitivity to identify the incident photons (energy loss) originating from the various possible processes crucial for the study of discrete symmetries.

## Analysis results

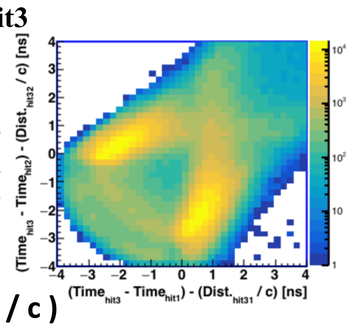



Distribution of **Sum Vs Difference** of two smallest angles in 3-hit events.

### Selection criterion of 511 keV

*Hits are **ordered in time** :* **Hit1 < Hit2 < Hit3**

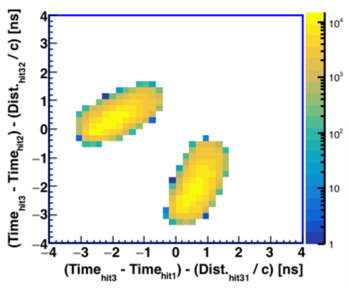
Angle difference between 1st and 2nd hits should be $180^0$. Scatter test was devised and used in order to assign the scattered gamma hit to the corresponding primary one.




**Scatter Test** = ( $Time\ diff_{Hits} - Distance_{Hits}$ / c )

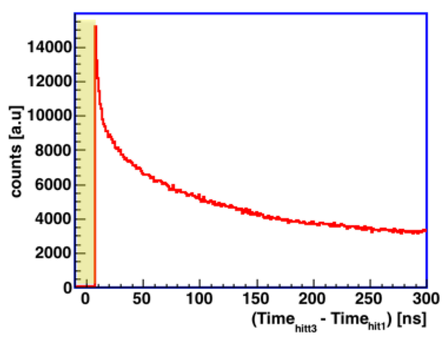
**Graphical cuts** for the allowed/true scatterings are implemented.

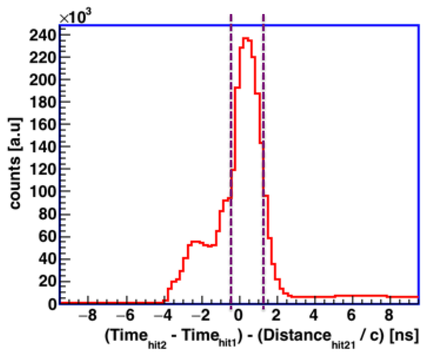
Event wise, scattered angles of the incident gammas and corresponding TOT values are estimated.




### Selection criterion of 1274.6 keV

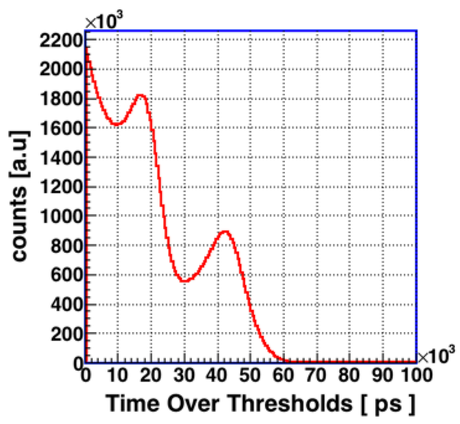
- All events when the angle between 1st and 2nd hit is around 180 degree are **filtered out**.
- Prompt gamma and scattered gammas are selected based on the hit-time (difference between 1st and 3rd hit) and the scatter test.

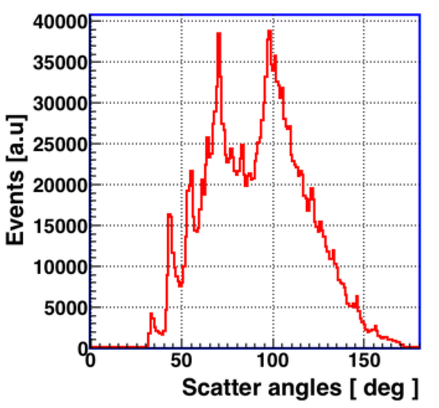


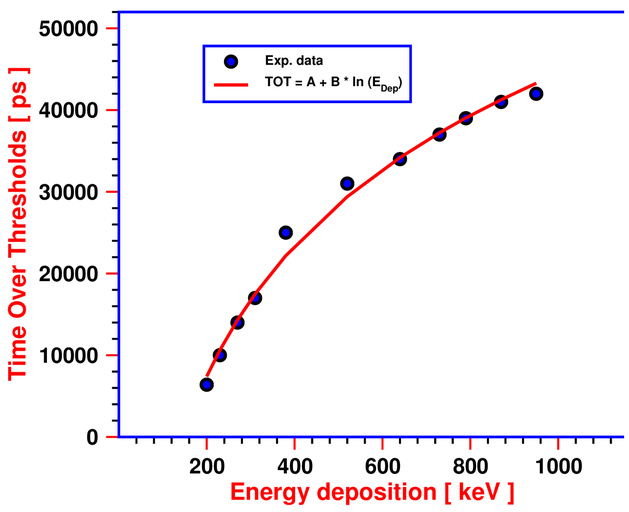

### TOT Vs $E_{dep}$ (Scatt. Angles)

**TOT** and **scattering angles** are plotted together for 511 keV and 1274.6 keV incident photons.

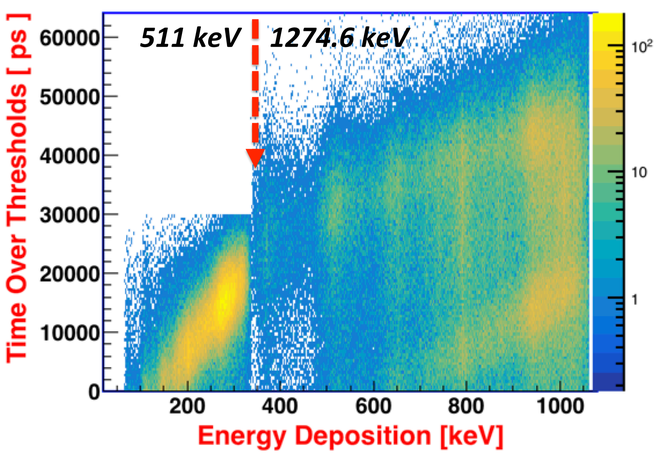



**TOT** Vs $\mathbf{E_{dep}}$ (evaluated with the known value of incident energy of gamma and its scattering angle) is plotted




Y-projections (TOT) were fitted for selected energy regions, which are most populated.




**References:**

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